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COMPILATION OF AIR POLLUTANT EMISSION FACTORS. SECOND EDITION. SUPPLEMENT NO. 2

Environmental Protection Agency
Research Triangle Park, North Carolina

September 1973

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16. ABSTRACT

This report is a supplement for "Compilation of Air Pollutant Emission Factors", AP-42. The scope of the second edition has been broadened to reflect expanding knowledge of emissions. The titles of the specific sections which are included in this supplement No. 2 are as follows: Introduction; Average Emission Factors for Highway Vehicles; and Light-Duty, Gasoline-Powered Vehicles. This supplement contains average emission factors for carbon monoxide, hydrocarbons (crankcase & evaporation & exhaust), nitrogen oxides, particulates and sulfur oxides.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air pollution Passenger vehicle Motor trucks Exhaust emissions Gasoline engines Diesel engines Particles Sulfur dioxide Carbon monoxide Nitrogen oxides	Emission factors Deterioration factor	13B

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PREFACE

This document reports data available on those atmospheric emissions for which sufficient information exists to establish realistic emission factors. The information contained herein is based on Public Health Service Publication 999-AP-42, *Compilation of Air Pollutant Emission Factors*, by R. L. Duprey, and on a revised and expanded version of *Compilation of Air Pollutant Emission Factors* that was published by the Environmental Protection Agency in February 1972. The scope of this second edition has been broadened to reflect expanding knowledge of emissions.

Chapters and sections of this document have been arranged in a format that permits easy and convenient replacement of material as information reflecting more accurate and refined emission factors is published and distributed. To speed dissemination of emission information, chapters or sections that contain new data will be issued – separate from the parent report – whenever they are revised.

To facilitate the addition of future materials, the punched, loose-leaf format was selected. This approach permits the document to be placed in a three-ring binder or to be secured by rings, rivets, or other fasteners. future supplements or revisions can then be easily inserted. The lower left- or right-hand corner of each page of the document bears a notation that indicates the date the information was issued.

Comments and suggestions regarding this document should be directed to the attention of Director, Monitoring and Data Analysis Division, Office of Air Quality Planning and Standards, Environmental Protection Agency, Research Triangle Park, N.C. 27711.

ACKNOWLEDGMENTS

Because this document is a product of the efforts of many individuals, it is impossible to acknowledge each individual who has contributed. Special recognition is given, however, to Environmental Protection Agency employees M. J. McGraw, A. J. Hoffman, J. H. Southerland, and R. L. Duprey for their efforts in the production of this work. Bylines identify the contributions of individual authors who revised specific sections and chapters.

Issuance	Release Date
Compilation of Emission Factors, Second Edition	*4/73*
Supplement No. 1	
Section 4.3, Storage of Petroleum Products	*7/73*
Section 4.4, Marketing and Transportation of Petroleum Products	
Supplement No. 2	
Introduction	
Section 3.1, Highway Vehicles	
Appendix, Table A-1	*9/73*

COMPILATION

OF

AIR POLLUTANT EMISSION FACTORS

INTRODUCTION

In the assessment of community air pollution, there is a critical need for accurate data on the quantity and characteristics of emissions from the numerous sources that contribute to the problem. The large number of individual sources and the diversity of source types make conducting field measurements of emissions on a source-by-source basis at the point of release impractical. The only feasible method of determining pollutant emissions for a given community is to make generalized estimates of typical emissions from each of the source types.

One of the most useful (and logical) tools for estimating typical emissions is the "emission factor," which is an estimate of the rate at which a pollutant is released to the atmosphere as a result of some activity, such as combustion or industrial production, divided by the level of that activity (also expressed in terms of a temporal rate). In other words, the emission factor relates the quantity of pollutants emitted to some indicator (activity level) such as production capacity, quantity of fuel burned, or vehicle miles traveled. In most cases, these factors are simply given as statistical or estimated averages; that is, no empirical information on the various process parameters (temperature, reactant concentrations, etc.) is considered in their calculation. However, for a few cases, such as in the estimation of hydrocarbon emissions from petroleum storage tanks, precise empirical formulas relating emissions to such variables as tank diameter, liquid storage temperature, and wind velocity have been developed. Because of their superior precision, emission factors based on empirical formulas are more desirable to obtain and can usually be given the highest accuracy rating. Factors derived from statistical averages, however, if based on an adequate number of field measurements ("source tests"), can also be both precise and accurate within practical and useful limits.

An example should illustrate how the factors are to be used:

Suppose a sulfuric acid plant, with a production rate of 200 tons/day of 100 percent acid, operates at an overall SO_2 to SO_3 conversion efficiency of 97 percent. Using the formula given as a footnote to Table 5.17-1 on page 5.17-5 of this publication, the uncontrolled sulfur dioxide emissions can be calculated:

SO_2 emissions = [-13.65 (% conversion efficiency) + 1365] x production rate

= [-13.65 (97%) + 1365] lb/ton acid x 200 tons acid/day

= 40 lb/ton acid x 200 tons acid/day

= 8000 lb/day (3632 kg/day)

The emission factors presented in this report have been estimated using a wide spectrum of techniques available for their determination. The preparation/revision of each factor section involves, first of all, the search for and obtainment of all the known written information on that source category from such sources as the Air Pollution Technical Information Center literature, Environmental Protection Agency technical reports (including emission test reports), and the National Emissions Data System point source file. After these data are reviewed, organized, and analyzed, the process descriptions, process flowsheets, and other background portions of the section are prepared. Then, using the compiled information, representative emission factors are developed for each pollutant emitted by each point source of the process category. As stated above, these factors are usually obtained by simply averaging the respective numerical data obtained. When feasible, the ranges in the factors are presented for further clarity. Occasionally, enough data exist to permit the development of either empirical or theoretical formulas (or graphs) relating emissions factors to various process parameters such as stream temperature, sulfur content, or catalyst. In these cases, representative values of these process parameters are selected and substituted into the formulas or graphs that, in turn, yield representative emission factors which are then tabulated within. The pertinent formulas and graphical data are also included in the section to allow the estimation of emission factors when the process conditions differ from those selected by the author(s).

After the draft of a section is completed, it is circulated for technical review to various personnel routinely familiar with the emission aspects of the particular activity. After these review comments are obtained and evaluated, the final draft is written and submitted for editing and publication.

The limitations and applicability of emission factors must be understood. To give some notion of the accuracy of the factors for a specific process, each process has been ranked as "A," "B," "C," "D," or "E." For a process with an "A" ranking, the emission factor should be considered excellent, i.e., based on field measurements of a large number of sources. A process ranked "B" should be considered above average, i.e., based on a limited number of field measurements. A ranking of "C" is considered average; "D," below average; and "E," poor. These rankings are presented below the table titles throughout the report.

The reader must be herein cautioned not to use these emission factors indiscriminately. That is, the factors generally will not permit the calculation of accurate emissions measurements from an individual installation. Only an on-site source test can provide data sufficiently accurate and precise to use in such undertakings as the design and purchase of control equipment or the initiation of a legal action. Factors are more valid when applied to a large number of processes, as, for example, when emission inventories are conducted as part of community or nationwide air pollution studies.

3.1.1 Average Emission Factors for Highway Vehicles

by David S. Kircher and Charles C. Masser

3.1.1.1 General – Emission factors in this section update emission factors for gasoline-powered motor vehicles presented in the February 1972 *Compilation of Air Pollutant Emission Factors*.[1] These new factors are based on nationwide statistical data for light-duty, gasoline-powered vehicles; heavy-duty, gasoline-powered vehicles; and heavy-duty, diesel-powered vehicles. Average emission factors are intended to assist those individuals interested in compiling approximate emission estimates for large areas, such as an individual state or the nation. The emission factor calculation techniques presented in sections 3.1.2 through 3.1.7 of this chapter are strongly recommended for the formulation of localized emission estimates required for air quality modeling or for the evaluation of air pollutant control strategies.

3.1.1.2 Emissions – Average emission factors by calendar year based on statistical data for the United States are presented in Table 3.1.1-1. These factors were calculated using the techniques described in sections 3.1.2, 3.1.4, and 3.1.5 of this chapter. Because the majority of highway vehicle emissions are produced (on a nationwide basis) by gasoline-powered light-duty vehicles and heavy-duty, gasoline- and diesel-powered vehicles, these are the only vehicles considered in Table 3.1.1-1. The emission contribution from diesel-powered, light-duty vehicles, from gaseous-fuel-powered vehicles, and from motorcycles is assumed to be insignificant for the purpose of developing these approximate factors.

The exhaust emission values presented in Table 3.1.1-1 for carbon monoxide, hydrocarbons, and nitrogen oxides are for an average speed of approximately 19.6 mi/hr (31.5 km/hr). These values can be modified to make them representative of the area for which emission estimates are being prepared, by using the average speed adjustment factors contained in Figure 3.1.1-1. For example, if carbon monoxide emissions in 1970 are to be estimated for a state where the average speed is 35 mi/hr, the appropriate emission factor would be 0.6 times 78 or 47 grams per mile. This value would then be multiplied by the total vehicle miles of travel (VMT) to arrive at a carbon monoxide emission estimate.

Crankcase and evaporative hydrocarbons, particulate, and sulfur oxide emission factors are average values that can be considered independent of speed. Emission estimates for these pollutants are calculated by simply multiplying the VMT by the emission factor.

Note: The emission factor data presented for highway vehicles in this chapter are based on a generalized test cycle that involves operation typical of every-day driving patterns. Because this driving cycle is intended to represent typical driving, it cannot apply in specific instances, i.e. to a particular segment of a particular roadway at a particular time. In order to estimate vehicular emissions under a specific set of conditions, "modal" emission factor data are required. Driving modes include: idle, constant speed, acceleration, and deceleration. Because all driving patterns can be divided into one of these four modes, emissions can be determined by summing the modal emissions for a particular driving pattern.

The Environmental Protection Agency is currently evaluating the use of modal emission data. Emission data for idle, various constant speeds, and various initial and final speeds (accelerations and decelerations) are being collected and analyzed. It is anticipated that these data will be published in Sections 3.1.2 and 3.1.4 in subsequent revisions of this publication. Modal data for light-duty vehicles (Section 3.1.2) will be published during 1973, and data for heavy-duty gasoline vehicles will be published at a later date.

Table 3.1.1-1. AVERAGE EMISSION FACTORS FOR HIGHWAY VEHICLES BASED ON NATIONWIDE STATISTICS[a]

Year	Carbon monoxide		Hydrocarbons				Nitrogen oxides (NO_x as NO_2)		Particulates				Sulfur oxides (SO_2)	
			Exhaust		Crankcase and evaporation				Exhaust		Tire wear			
	g/mi	g/km	g/mi	g/km	g/mi	g/km	g/mi	g/km	g/mi	g/km	g/mi	g/km	g/mi	g/km
1965	89	55	9.2	5.7	5.8	3.6	4.8	3.0	0.38	0.24	0.20	0.12	0.20	0.12
1970	78	48	7.8	4.8	3.9	2.4	5.3	3.3	0.38	0.24	0.20	0.12	0.20	0.12
1971	74	46	7.2	4.5	3.5	2.2	5.4	3.4	0.38	0.24	0.20	0.12	0.20	0.12
1972	68	42	6.6	4.1	2.9	1.8	5.4	3.4	0.38	0.24	0.20	0.12	0.20	0.12
1973	62	39	6.1	3.8	2.4	1.5	5.4	3.4	0.38	0.24	0.20	0.12	0.20	0.12
1974	56	35	5.5	3.4	2.0	1.2	5.2	3.2	0.38	0.24	0.20	0.12	0.20	0.12
1975	50	31	5.0	3.1	1.5	0.93	5.0	3.1	0.38	0.24	0.20	0.12	0.20	0.12
1976	44	27	4.3	2.7	1.3	0.81	4.8	3.0	0.38	0.24	0.20	0.12	0.20	0.12
1977	37	23	3.7	2.3	1.0	0.62	4.3	2.7	0.38	0.24	0.20	0.12	0.20	0.12
1978	31	19	3.2	2.0	0.83	0.52	3.8	2.4	0.38	0.24	0.20	0.12	0.20	0.12
1979	27	17	2.7	1.7	0.67	0.42	3.4	2.1	0.38	0.24	0.20	0.12	0.20	0.12
1980	23	14	2.4	1.5	0.53	0.33	3.1	1.9	0.38	0.24	0.20	0.12	0.20	0.12
1990	12	7.5	1.3	0.81	0.38	0.24	1.8	1.1	0.38	0.24	0.20	0.12	0.20	0.12

[a]Based on sections 3.1.2, 3.1.4, and 3.1.5 and on References 2 through 4.

NOTE: This table reflects interim standards promulgated by the EPA Administrator on April 11, 1973, and in July 1973.

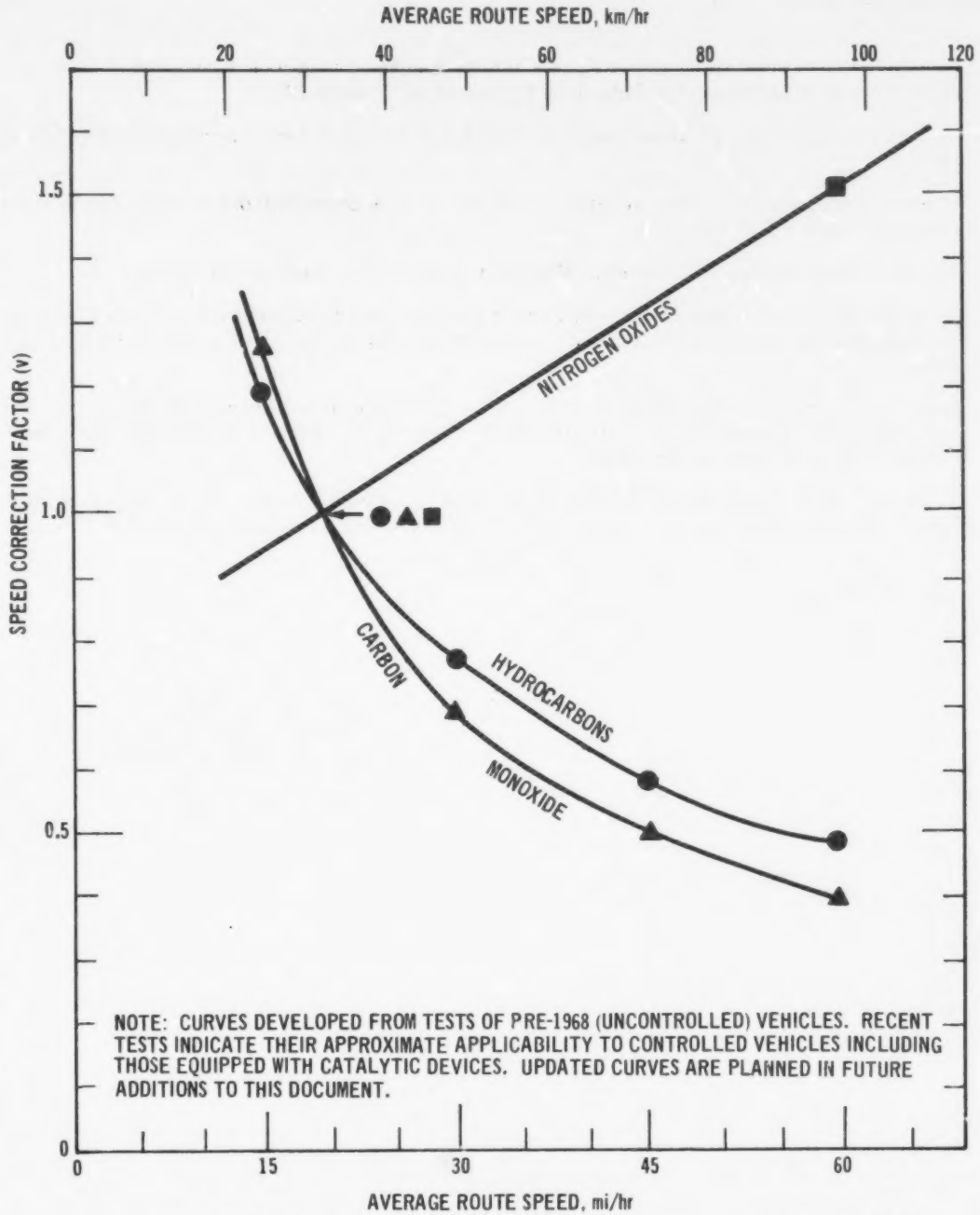

Figure 3.1.1-1. Average speed correction factors for all model years.[5-7]

References for Section 3.1.1

1. Compilation of Air Pollutant Emission Factors. U.S. Environmental Protection Agency, Office of Air Programs. Research Triangle Park, N.C. Publication Number AP-42. February 1972.

2. Highway Statistics 1970. U.S. Department of Transportation, Federal Highway Administration. Washington, D.C. 1971.

3. Census of Transportation – Truck Inventory and Use Survey. U.S. Department of Commerce, Bureau of the Census. Washington, D.C. July 1970.

4. Automotive Facts and Figures. Automobile Manufacturers Association. Washington, D.C. July 1970.

5. McMichael, W.F. and A.H. Rose, Jr. A Comparison of Emissions from Automobiles in Cities at Two Different Altitudes. U.S. Department of Health, Education and Welfare, Public Health Service. Cincinnati, Ohio. July 1965.

6. Study of Emissions from Light-Duty Vehicles in Six Cities. Automotive Environmental Systems Inc. San Bernadino, Calif. Prepared for the Environmental Protection Agency. Research Triangle Park, N.C., under Contract Number 68-04-0042. June 1972.

7. Walsh, M.P., Unpublished data on emissions from a catalyst-equipped light duty vehicle. The City of New York Department of Air Resources, Bureau of Motor Vehicle Pollution Control. New York, N.Y. November 1972.

3.1.2 Light-Duty, Gasoline-Powered Vehicles

by David S. Kircher and Charles C. Masser

3.1.2.1 General – Because of their widespread use, light-duty, gasoline-powered highway vehicles are responsible for a large percentage of the total emissions from highway vehicles on a nationwide as well as on a regionwide basis. The information contained in this section permits the calculation of emission factors for this class of highway vehicles operated in a specific geographic area under study. Section 3.1.1 provided generalized emission factors for all highway vehicles combined; this section provides the information necessary to *calculate* emission factors for one class of vehicles by using the technique outlined below.

3.1.2.2 Carbon Monoxide, Hydrocarbon, and Nitrogen Oxide Emissions – The calculation of light-duty vehicle exhaust emission factors for carbon monoxide, hydrocarbons, and nitrogen oxides can be expressed mathematically as:

$$e_{np} = \sum_{i=n-12}^{n+1} c_i\, d_i\, m_i\, s_i \qquad (1)$$

where: e_{np} = Emission factor in grams per vehicle mile for calendar year (n), and pollutant (p)

c_i = The 1975 Federal test procedure emission rate for pollutant (p) in g/mi for the i^{th} model year at low mileage [1,2]

d_i = The controlled vehicle pollutant (p) emission deterioration factor for the i^{th} model year at calendar year (n)

m_i = The weighted annual travel of the i^{th} model year during calendar year (n). The determination of this variable involves the use of the vehicle model year distribution

s_i = The weighted speed adjustment factor for the i^{th} model year vehicles

In addition to exhaust emission factors, the calculation of hydrocarbon emissions from gasoline motor vehicles involves evaporative and crankcase hydrocarbon emission rates. Evaporation and crankcase emissions can be determined using:

$$f_n = \sum_{i=n-12}^{n+1} h_i\, m_i \qquad (2)$$

where: f_n = The combined evaporative and crankcase hydrocarbon emission factor for calendar year (n)

h_i = The combined evaporative and crankcase emission rate for the i^{th} model year

m_i = The weighted annual travel of the i^{th} model year during calendar year (n)

A brief discussion of each of the variables presented in the above equations is necessary to help clarify their formulation and use. These discussions amplify the definitions at the beginning of the chapter.

Test cycle emission rates (c and h). A recent study of light-duty vehicle exhaust emission rates in six cities resulted in the data for 1971 and earlier model years that are presented in Tables 3.1.2-1 and 3.1.2-2.[3] Emission

Table 3.1.2-1. CARBON MONOXIDE, HYDROCARBON, AND NITROGEN OXIDE EMISSION FACTORS FOR LIGHT-DUTY VEHICLES AT LOW AND HIGH ALTITUDE[a]

EMISSION FACTOR RATING: A

Location and pollutant	Exhaust emission factors at low mileage per model year[b]									
	Pre 1968	1968	1969	1970	1971	1972[c]	1973 through 1974[c]	1975[d]	1976[e]	Post 1976[e]
Low altitude (excluding Calif.)										
Carbon monoxide										
g/mi	87	46	39	36	34	19	19	12.5	1.8	1.8
g/km	54	29	24	22	21	12	12	7.8	1.1	1.1
Exhaust hydrocarbons										
g/mi	8.8	4.5	4.4	3.6	2.9	2.7	2.7	1.3	0.23	0.23
g/km	5.5	2.8	2.7	2.2	1.8	1.7	1.7	0.81	0.14	0.14
Nitrogen oxides										
g/mi	3.6	4.3	5.5	5.1	4.8	4.8	2.3	2.2	1.6	0.31
g/km	2.2	2.7	3.4	3.2	3.0	3.0	1.4	1.4	1.0	0.19
High altitude (excluding Calif.)										
Carbon monoxide										
g/mi	130	74	48	72	75	42	42	20	1.8	1.8
g/km	81	46	30	45	47	26	26	12	1.1	1.1
Exhaust hydrocarbons										
g/mi	10	6.0	5.4	6.1	5.3	4.9	4.9	1.8	0.23	0.23
g/km	6.2	3.7	3.4	3.8	3.3	3.0	3.0	1.1	0.14	0.14
Nitrogen oxides										
g/mi	1.9	2.2	2.6	2.8	3.1	3.1	1.4	1.4	1.3	0.31
g/km	1.2	1.4	1.6	1.7	1.9	1.9	0.87	0.87	0.81	0.19

[a] References 2 through 6.

[b] Pre-1968 results are not at low mileage but are arithmetic means of tests of a random sample of vehicles. There is no reason to present low mileage emission rates for pre-1968 vehicles because they are not subject to exhaust control device deterioration.

[c] Estimates based on the relationship of low mileage emissions to standards for 1971 and earlier controlled vehicles.

[d] Based on estimates for the interim emissions standards.

[e] Based on estimates in Reference 6.

NOTE: This table has been revised to reflect interim light duty vehicle standards promulgated by the EPA Administrator.

Table 3.1.2-2. CARBON MONOXIDE, HYDROCARBON, AND NITROGEN OXIDES EMISSION FACTORS FOR LIGHT-DUTY VEHICLES, STATE OF CALIFORNIA ONLY[a]

EMISSION FACTOR RATING: A

	Exhaust emission factors at low mileage per model year[b]											
Pollutant	Pre 1966	1966	1967	1968	1969	1970	1971	1972[c]	1973 through 1974[c]	1975[d]	1976[e]	Post 1976[e]
Carbon monoxide												
g/mi	87	51	50	46	39	36	34	19	19	2.8	1.8	1.8
g/km	54	32	31	29	24	22	21	12	12	1.7	1.1	1.1
Exhaust hydrocarbons												
g/mi	8.8	6.0	4.6	4.5	4.4	3.6	2.9	2.7	2.7	0.33	0.23	0.23
g/km	5.5	3.7	2.9	2.8	2.7	2.2	1.8	1.7	1.7	0.21	0.14	0.14
Nitrogen oxides												
g/mi	3.6	3.4	3.4	4.3	5.5	5.1	3.5	3.5	2.3	1.1	1.1	0.31
g/km	2.2	2.1	2.1	2.7	3.4	3.2	2.2	2.2	1.4	0.68	0.68	0.19

[a] References 2 through 6.
[b] Pre-1968 results are not at low mileage but are arithmetic means of tests of a random sample of vehicles. There is no reason to present low mileage emission rates for pre-1968 vehicles because they are not subject to exhaust control device deterioration.
[c] Estimates based on the relationship of low mileage emissions to standards for 1971 and earlier controlled vehicles.
[d] Based on estimates for the interim emissions standards.
[e] Based on estimates in Reference 5. These are not test results.

NOTE: This table has been revised to reflect interim light duty vehicle standards promulgated by the EPA Administrator.

Table 3.1.2-3. LIGHT-DUTY VEHICLE CRANKCASE AND EVAPORATIVE HYDROCARBON EMISSIONS BY MODEL YEAR FOR ALL AREAS EXCEPT CALIFORNIA[a]
EMISSION FACTOR RATING: C

Model year	Hydrocarbons	
	g/mi	g/km
Pre-1963	7.1	4.4
1963 through 1967	3.8	2.4
1968 through 1970	3.0	1.9
1971	0.5	0.3
1972	0.2	0.1
Post-1972	0.2	0.1

[a] Reference 7.

Table 3.1.2-4. LIGHT-DUTY VEHICLE CRANKCASE AND EVAPORATIVE HYDROCARBON EMISSIONS BY MODEL YEAR FOR CALIFORNIA[a]
EMISSION FACTOR RATING: C

Model year	Hydrocarbons	
	g/mi	g/km
Pre-1961	7.1	4.4
1961 through 1963	3.8	2.4
1964 through 1967	3.0	1.9
1968 through 1969	3.0	1.9
1970 through 1971	0.5	0.3
1972	0.2	0.1
Post- 1972	0.2	0.1

[a] Reference 7.

rates for 1972 and later vehicles in these tables are based primarily on the applicable California and Federal emission standards. These standards were modified to reflect low-mileage emission rates using information provided in the references.[4,5] Reference 4 also provided the information necessary to modify the 1971 and earlier test results to low-mileage emission rates. Evaporative and crankcase hydrocarbon emission values are shown in Tables 3.1.2-3 and 3.1.2-4. Test cycle emission rates are presented for both low and high altitudes (exhaust emissions) and for California and all areas except California (exhaust, evaporative, and crankcase emissions). High-altitude areas are considered separately because of the significant impact altitude has on carbon monoxide, hydrocarbon, and nitrogen oxide exhaust emissions. California is considered separately because emission control standards were implemented there on a different and somewhat more accelerated schedule than were the Federal emission standards.

Deterioration factors (d). Exhaust deterioration factors for emission controlled vehicles by model year and pollutant are presented in Tables 3.1.2-5 and 3.1.2-6. Deterioration factors enable the modification of low mileage emission rates to account for the ageing or deterioration of exhaust emission control devices. The deterioration rates presented were derived primarily from testing done by the California Air Resources Board.[4]

Weighted annual mileage (m). The determination of the weighted annual mileage is best illustrated by the example in Table 3.1.2-7. In this example, the model year distribution as of July 1 (in this case nationwide) is combined with nationwide annual travel by model year, unless localized annual mileages by model year are available. In the calculation of city-specific emission factors, the model year distribution for the area under consideration should be obtained from registration statistics and combined with the annual mileages as in Table 3.1.2-7.

Weighted speed adjustment factor (s). The weighted speed adjustment factor enables the calculation of a region-wide emission factor that takes into account variation in average route speed. This variable is calculated using:

$$s_i = \sum_{j=1}^{n} f_j v_j \qquad (3)$$

where: s_i = The weighted speed adjustment factor for the i^{th} model year

f_j = The fraction of total annual vehicle miles traveled at speed (j)

v_j = The vehicular average speed correction factor for average speed (j)

The values for the vehicular speed adjustment factor (v) are contained in Figure 3.1.1-1.

3.1.2.3 Particulate and Sulfur Oxide Emissions – Light-duty, gasoline-powered vehicles emit relatively small quantities of particulate and sulfur oxides in comparison with the three pollutants discussed above. For this reason, average rather than calculated emission factors should be sufficiently accurate for approximating particulate and sulfur oxide emissions from light-duty, gasoline-powered vehicles. Average emission factors for these pollutants are presented in Table 3.1.2-8. No Federal standards for these two pollutants are presently in effect, although many areas do have opacity (antismoke) regulations applicable to motor vehicles.

Table 3.1.2-5. CARBON MONOXIDE, EXHAUST HYDROCARBON, AND NITROGEN OXIDES DETERIORATION FACTORS (d) FOR LIGHT-DUTY, GASOLINE-POWERED VEHICLES IN ALL AREAS EXCEPT CALIFORNIA[a]

Pollutant and model year	Vehicle age, years									
	0	1	2	3	4	5	6	7	8	≥9
Carbon monoxide										
Pre-1968[b]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1968	1.00	1.24	1.35	1.41	1.47	1.53	1.58	1.63	1.67	1.72
1969	1.00	1.42	1.53	1.59	1.63	1.68	1.71	1.75	1.79	1.82
1970 through 1974[c]	1.00	1.18	1.32	1.38	1.40	1.44	1.47	1.50	1.51	1.56
1975[d]	1.00	1.04	1.30	1.36	1.43	1.44	1.49	1.56	1.63	1.69
Post 1975[d]	1.00	1.16	1.34	1.50	1.62	1.75	1.88	2.00	2.10	2.22
Exhaust hydrocarbon										
Pre-1968[b]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1968	1.00	1.12	1.18	1.21	1.23	1.26	1.28	1.30	1.32	1.35
1969	1.00	1.10	1.16	1.18	1.21	1.23	1.25	1.28	1.29	1.31
1970 through 1974[c]	1.00	1.05	1.10	1.13	1.15	1.17	1.20	1.22	1.24	1.26
1975[d]	1.00	1.00	1.13	1.22	1.29	1.37	1.43	1.50	1.56	1.63
Post 1975[d]	1.00	1.14	1.30	1.44	1.55	1.67	1.77	1.88	1.96	2.07
Nitrogen oxides										
Pre 1973[b]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1973 through 1974[e]	1.00	1.11	1.18	1.20	1.21	1.22	1.23	1.24	1.25	1.26
1975[d]	1.00	1.00	1.18	1.23	1.23	1.41	1.45	1.45	1.45	1.45
1976[d]	1.00	1.03	1.07	1.10	1.13	1.17	1.19	1.21	1.24	1.26
Post 1976[d]	1.00	1.17	1.37	1.53	1.67	1.82	1.94	2.06	2.17	2.32

[a] References 4 and 5.

[b] Values of unity are given for Pre-1968 vehicles because they were not equipped with exhaust control devices and, therefore, are not subject to exhaust control device deterioration. Deterioration in the emission performance of pre-1968 vehicles because of poor maintenance, age, etc., is taken into account by their emission factors, which are based on a random sample of vehicles.

[c] Based on test results for 1970 model year vehicles.

[d] Based on Reference 5 and on unpublished EPA test data. Deterioration factors based on tests of prototype 1976-1977 model year vehicles.

[e] Based on test results for 1971 (California) model year vehicles.

Table 3.1.2-6. CARBON MONOXIDE, EXHAUST HYDROCARBON, AND NITROGEN OXIDES DETERIORATION FACTORS (d) FOR LIGHT-DUTY, GASOLINE-POWERED VEHICLES IN CALIFORNIA[a]

Pollutant and model year	Vehicle age, years									
	0	1	2	3	4	5	6	7	8	≥9
Carbon monoxide										
Pre-1966[b]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1966	1.00	1.13	1.21	1.24	1.25	1.28	1.29	1.31	1.32	1.34
1967	1.00	1.11	1.18	1.23	1.29	1.35	1.40	1.46	1.50	1.56
1968	1.00	1.24	1.35	1.41	1.47	1.53	1.58	1.63	1.67	1.72
1969	1.00	1.42	1.53	1.59	1.63	1.68	1.71	1.75	1.79	1.82
1970 through 1974[c]	1.00	1.18	1.32	1.38	1.40	1.44	1.47	1.50	1.51	1.56
Post-1974[d]	1.00	1.16	1.34	1.50	1.62	1.75	1.88	2.00	2.10	2.22
Hydrocarbon										
Pre-1966[b]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1966	1.00	1.14	1.22	1.25	1.27	1.29	1.30	1.32	1.35	1.35
1967	1.00	1.07	1.10	1.12	1.14	1.15	1.17	1.18	1.20	1.21
1968	1.00	1.12	1.18	1.21	1.23	1.26	1.28	1.30	1.32	1.35
1969	1.00	1.10	1.16	1.18	1.21	1.23	1.25	1.28	1.29	1.31
1970 through 1974[c]	1.00	1.05	1.10	1.13	1.15	1.17	1.20	1.22	1.24	1.26
Post-1974[d]	1.00	1.14	1.30	1.44	1.55	1.67	1.77	1.88	1.96	2.07
Nitrogen oxides										
Pre-1970[b]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1971 through 1974[e]	1.00	1.11	1.18	1.20	1.21	1.22	1.23	1.24	1.25	1.26
1975[d]	1.00	1.03	1.07	1.10	1.13	1.17	1.19	1.21	1.24	1.26
1976d	1.00	1.03	1.07	1.10	1.13	1.17	1.19	1.21	1.24	1.26
Post-1976[d]	1.00	1.17	1.37	1.53	1.67	1.82	1.94	2.06	2.17	2.32

[a] References 4 and 5.

[b] Values of unity are given for these model years because the vehicles were not equipped with exhaust control devices and, therefore, are not subject to exhaust control device deterioration. Deterioration in the emission performance of these vehicles because of poor maintenance, age, etc., is taken into account by their emission factors, which are based on a random sample of vehicles.

[c] Based on test results for 1970 model year vehicles.

[d] Based on Reference 5 and on unpublished EPA test data. Deterioration factors based on tests of prototype 1975-1976 model year vehicles.

[e] Based on test results for 1971 (California) model year vehicles.

Table 3.1.2-7. SAMPLE CALCULATION OF WEIGHTED LIGHT-DUTY VEHICLE ANNUAL TRAVEL[a]

Age, years	Fraction of total vehicles in use nationwide (a)[b]	Average annual miles driven (b)[c]	a x b	Annual travel (m)[d]
0[e]	0.000	15,300	0	0.000
1	0.078	15,900	1,240	0.107
2	0.116	15,000	1,740	0.151
3	0.110	14,000	1,540	0.133
4	0.098	13,100	1,284	0.111
5	0.106	12,200	1,293	0.112
6	0.106	11,300	1,198	0.104
7	0.088	10,300	906	0.078
8	0.078	9,400	733	0.063
9	0.063	8,500	536	0.046
10	0.041	7,600	312	0.027
11	0.035	6,700	235	0.020
12	0.021	6,700	141	0.012
≥13	0.060	6,700	402	0.036

[a]References 8 and 9.
[b]These data are for July 1, 1970, from Reference 8 and represent the U.S. population of light-duty vehicles by model year.
[c]Mileage values are the results of at least squares analysis of data in Reference 9.
[d] $m = \frac{ab}{\Sigma ab}$
[e]Refers to "next" year's models introduced in the fall.

Table 3.1.2-8. PARTICULATE AND SULFUR OXIDES EMISSION FACTORS FOR LIGHT-DUTY, GASOLINE-POWERED VEHICLES
EMISSION FACTOR RATING: C

Pollutant	Emissions	
	g/mi	g/km
Particulate[a]		
Exhaust	0.34	0.21
Tire wear	0.20	0.12
Sulfur oxides[b] (SO_x as SO_2)	0.13	0.08

[a]References 10, 11, and 12.
[b]Based on an average fuel consumption of 13.6 mi/gal (5.8 km/liter) from Reference 8 and on the use of a fuel with a 0.032 percent sulfur content from References 13 through 15, and a density of 6.1 lb/gal (0.73 kg/liter) from References 13 and 14.

APPENDIX

Note: Previous editions of *Compilation of Air Pollutant Emission Factors* presented a table entitled Percentage Distribution by Size of Particles from Selected Sources without Control Equipment. Many of the data have become obsolete with the development of new information. As soon as the new information is sufficiently refined, a new table, complete with references, will be published for addition to this document.

Table A-1. NATIONWIDE EMISSIONS FOR 1971 [a]

Pollutant	Stationary combustion		Solid waste disposal		Mobile combustion		Industrial processes		Miscellaneous		Total[b]	
	ton/yr	Mg/yr[c]	ton/yr	Mg/yr	ton/yr	Mg/yr	ton/yr	Mg/yr	ton/yr	Mg/yr	ton/yr	Mg/yr
Particulates	6,500,000	5,900,000	700,000	600,000	1,000,000	900,000	13,500,000	12,200,000	5,200,000	4,800,000	26,900,000	24,400,000
Sulfur oxides	26,300,000	23,900,000	100,000	100,000	1,000,000	1,000,000	5,100,000	4,600,000	100,000	100,000	32,600,000	29,700,000
Carbon monoxide	1,000,000	900,000	3,800,000	3,400,000	77,500,000	70,200,000	11,400,000	10,300,000	6,500,000	5,900,000	100,200,000	90,700,000
Hydrocarbons	300,000	300,000	1,000,000	900,000	14,700,000	13,300,000	5,600,000	5,100,000	5,000,000	4,500,000	26,600,000	24,100,000
Nitrogen oxides	10,200,000	9,300,000	200,000	200,000	11,200,000	10,200,000	200,000	200,000	200,000	200,000	22,000,000	20,100,000

[a]Reference 1.

[b]Some totals may be rounded to a convenient number of figures.

[c]Mg - megagrams.